The Management of the COVID-19 Patient with Respiratory Failure

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### Coronaviruses

- **Hosts:** humans, other mammals, birds
- **Frequent cause of the common cold**
  - Accounts for 5-10% of adult URIs
- **Typical symptoms:** fever, cough, sore throat
- Can cause viral pneumonia or bronchitis
- Primarily occur in winter and early spring
- Spread by aerosol droplets and contact with secretions
- No effective vaccines or approved antivirals
  - Investigational antivirals available for compassionate use

### COVID-19

- **Virus = SARS-CoV-2**
- Originated in Wuhan, China November 2019
- Coronavirus strains causing severe illness:
  - SARS*
  - MERS*
  - COVID-19 *

*These strains do NOT present like the common cold and present with flu-like symptoms
## Mortality Rates Of Viral Outbreaks

- **1918 – 1919 Influenza**: 10%
- **2002 – 2004 SARS**: 10%
- **2014 – 2017 MERS**: 37%
- **2019 – 2020 COVID-19**: 3.7%

### Influenza 2019-2020 Season

<table>
<thead>
<tr>
<th>CDC estimates* that, from October 1, 2019, through March 7, 2020, there have been:</th>
</tr>
</thead>
<tbody>
<tr>
<td>36,000,000 – 51,000,000 flu illnesses</td>
</tr>
<tr>
<td>17,000,000 – 24,000,000 flu medical visits</td>
</tr>
<tr>
<td>370,000 – 670,000 flu hospitalizations</td>
</tr>
<tr>
<td>22,000 – 55,000 flu deaths</td>
</tr>
</tbody>
</table>
COVID-19 mortality by age

![Chart showing COVID-19 mortality by age](chart.png)

Common Presenting Symptoms

![Chart showing common presenting symptoms of COVID-19](chart.png)

N = 201

### Symptoms at Presentation

![Bar chart showing percentages of patients with various symptoms at presentation](image)

- **Fever with cough:** 100.00%
- **Fever with dyspnea:** 40.00%
- **Fever with fatigue, myalgia or headache:** 20.00%
- **Fever alone:** 0.00%

**Combined Symptoms**

N = 201


---

### Median Timeline of Disease Progression

<table>
<thead>
<tr>
<th>Onset of Illness</th>
<th>7 days</th>
<th>8 days</th>
<th>9 days</th>
<th>10.5 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital Admission</td>
<td>Dyspnea</td>
<td>ARDS</td>
<td>Mechanical Ventilation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ICU Admission</td>
<td></td>
</tr>
</tbody>
</table>

Risk Factors for Respiratory Failure: Wuhan Jinyintan Hospital, China

- 84 of 201 patients (42%) developed ARDS
  - 44 of 84 patients (52%) died
- Average hospital stay – 13 days
- 71% discharged (6.5% still hospitalized at time of writing)


Risk Factor for Respiratory Failure: Wuhan Jinyintan Hospital, China

- ARDS risk factors:
  - Older age
  - Neutrophilia
  - Elevated LDH or D-dimer
- High fever at presentation was a risk for ARDS but was also associated with a lower mortality

Respiratory Management: Wuhan Jinyintan Hospital, China

Clinical Characteristics of Hospitalized Patients: Zhongnan Hospital of Wuhan University, China

- 138 patients
  - 40 of these were healthcare workers
- Median age = 56 years
  - ICU median = 66 years
  - Non-ICU = 51 years
- Symptoms:
  - Fever (98.6%)
  - Fatigue (69.6%)
  - Cough (59.4%)
- Chest CT: bilateral patchy or ground glass infiltrates in all patients
Clinical Characteristics of Hospitalized Patients: Zhongnan Hospital of Wuhan University, China

- 36 patients (26.1%) of patients required ICU care; of these:
  - ARDS (61.1%)
  - Arrhythmia (44.4%)
  - Shock (30.6%)
- Median time intervals:
  - Symptom onset to dyspnea: 5 days
  - Symptom onset to hospitalization: 7 days
  - Symptoms onset to ARDS: 8 days
- Average hospital stay = 10 days
- Average mortality = 4.3%

ICU respiratory management:
- 11.1% heated high flow oxygen
- 41.7% non-invasive ventilation
- 47.2% intubation and mechanical ventilation
  - 4 of these switched to ECMO
- 36% of patients required vasopressors
- 2 patients required dialysis

JAMA 2020; 3231061-9
Patients Needing ICU Care

- Older persons (mean age is about 60 years old)
- Co-morbid disease
  - Diabetes
  - Cardiac disease
  - Hypertension
- Most common reason for needing ICU = ARDS

JAMA. Published online March 11, 2020. doi:10.1001/jama.2020.3633

Cause of Death due to COVID

Risks for mortality in COVID-19 infection

- Older age
- Co-morbidities
  - Hypertension
  - Diabetes
  - Heart disease
- Persistent lymphopenia
- Rising D-dimer
- Rising LDH
- Rising troponin

www.thelancet.com Published online March 9, 2020
https://doi.org/10.1016/S0140-6736(20)30566-3
ICU Utilization: Italian Lombardi ICU Network


CT Findings In COVID

- 17 patients admitted to West China - Guang’an Hospital of Sichuan University  
  • Average 4 days symptoms prior to admission  
  • Findings:  
    • 70% ground glass opacities  
    • 30% ground glass + consolidative opacities

- Location:  
  • 82% bilateral  
  • 18% unilateral  
  • 88% had both upper & lower lobe involvement  
  • There were no  
    • Pleural effusions  
    • Tree-in-bud infiltrates  
    • Cavities

Day #1

Day #2
Day #3
Management of Respiratory Failure in COVID-19

• Certain procedures and therapies may result in aerosolization of the virus

• Consider avoiding
  • High flow nasal cannula (>6LPM O2)
  • Heated high flow nasal cannula
  • Non-Invasive Positive Pressure Ventilation (unless closed exhalation circuit)
  • Nebulizers, intrapulmonary percussive ventilation, percussive chest physiotherapy, and Metanebs
  • Bronchoscopy

Management of Respiratory Failure in COVID-19

• If feasible, consider early intubation in patients requiring >6LNC
  • Reduces aerosols. Also, temporizing measures may delay intubation
  • Experienced intubator
  • Rapid Sequence Intubation (RSI) with paralytic.
  • Video Laryngoscopy may allow operator more distance from airway
  • Bougie may increase first pass success
  • PPE: N95, contact, and droplet precautions
  • Airborne Infection Isolation Room
Management of Critical Illness

- Hemodynamic supports as needed, keep MAP \( \geq 65 \)
  - 1\(^{st}\) line in septic shock: norepinephrine
  - 2\(^{nd}\) line: vasopressin
  - 3\(^{rd}\) line: epinephrine
- Judicious fluid resuscitation in hypoxic respiratory failure
- Evaluate for organ dysfunction: Urine output/creatinine, liver function testing and echocardiogram,
- Consider impact of testing on hospital decontamination; will bedside or point of care testing suffice?

Don’t Miss The Mimics

<table>
<thead>
<tr>
<th>Cardiogenic pulmonary edema</th>
<th>Other forms of pneumonia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical exam: S3 or S4, elevated JVP, moist crackles?</td>
<td>Influenza</td>
</tr>
<tr>
<td>Elevated BNP level?</td>
<td>Bacterial pneumonia</td>
</tr>
<tr>
<td>Cardiac echo?</td>
<td>If they present with sepsis, start antibiotics immediately</td>
</tr>
</tbody>
</table>
Respiratory failure in COVID-19 is due to ARDS

Normal (low power)

ARDS (high power)
Fluid Balance across the Lung

Movement of fluid across each compartment can be predicted by "Starling's Law"

Starling's Law can be completely derived by Ω's Law

\[ V = IR \]

\[ I = \text{Conductance (Pressure Gradient)} \]

\[ J_v = K_f c \left[ (P_{pc} - P_T) - \sigma(\Pi_p - \Pi_T) \right] \]

**Hydrostatic**
- Flux of volume
- Permeability (filtration)
- Coefficient for H₂O

**Oncotic**
- Pulmonary Hydrostatic Pressure
- Plasma Oncotic Pressure
- Tissue Hydrostatic Pressure
- Reflection coefficient

1.0 means all reflected

Normal lung

- Alveolus
- Basement Membrane
- Capillary
Hydrostatic Colloid Oncotic Alveolus
Cardiogenic Pulmonary Edema
Basement Membrane
Capillary

Acute Respiratory Distress Syndrome
Basement Membrane
Capillary
Zone 1

\[ P_A > P_a > P_v \]

Zone 2

\[ P_a > P_A > P_v \]

Zone 3

\[ P_a > P_v > P_A \]

Effect of lying down supine

Zone 1  Anterior - chest

\[ P_A > P_a > P_v \]

Zone 2

\[ P_a > P_A > P_v \]

\[ P_a > P_v > P_A \]

Zone 3  Posterior - back

\[ P_a > P_v > P_A \]

\[ P_A = \text{alveolar pressure} \]

\[ P_a = \text{arterial pressure} \]

\[ P_v = \text{venous pressure} \]
In ARDS, the dependent parts of the lung are often the worst.

So, what if you could flip the patient over?
The treatment of ARDS is PEEP
How The Mortality Rate Of ARDS Was Reduced By 22%

- **High Volume Group**
  - Starting Vt = 12 ml/kg
  - Kept plateau pressure < 50 cm
- **Low Volume Group**
  - Starting Vt = 6 ml/kg
  - Kept plateau pressure < 30 cm

![Graph showing mortality rate comparison between low tidal volume and high tidal volume.](N Engl J Med 2000; 342:1301-1308)
# COVID-19 Do’s and Don’ts

<table>
<thead>
<tr>
<th><strong>DO:</strong></th>
<th><strong>DON’T:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• DVT prophylaxis</td>
<td>• Routinely use corticosteroids</td>
</tr>
<tr>
<td>• GI prophylaxis</td>
<td>• Over-sedate patients</td>
</tr>
<tr>
<td>• 30-45 degree bed elevation</td>
<td>• Routinely use paralytics</td>
</tr>
<tr>
<td>• Vasopressors for MAP &lt; 65</td>
<td>• Use hypotonic crystalloids or colloid solutions for shock</td>
</tr>
<tr>
<td>• Enteral nutrition within 24-48 hours</td>
<td></td>
</tr>
</tbody>
</table>

**WHO guideline:** *Clinical management of severe acute respiratory infection (SARI) when COVID-19 disease is suspected*

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**The disaster that you drill for is not the disaster that you get**
Planning for ICU surge capacity

- Are there other hospital locations that can be converted to ICU?
  - Step-down units
  - Surgical post-op recovery areas
  - Cath lab recovery areas
  - Endoscopy rooms and recovery areas
  - Operating rooms
- Are there other staff that can be deployed for ICU care?
- Can you acquire additional ventilators?
- Do you have additional dialysis capacity?

The Management of the COVID-19 Patient with Respiratory Failure

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Mechanical ventilation topics

1. Ventilators
   a) Modes
   b) Oxygenation and ventilation
   c) Settings
2. ARDS
   a) Low tidal volume ventilation
   b) Prone positioning
3. Refractory hypoxemia
4. Liberation from the vent

Ventilator modes

- Assist Control
- SIMV
- Pressure Support
Ventilator modes

- Assist Control
- SIMV
- Pressure Support
  - No set rate

Set respiratory rate

- Assist Control
  - Full support each breath
- SIMV
  - Full support on ventilator-initiated breaths
  - Partial support on patient-initiated breaths
- Pressure Support
Ventilator modes

- Assist Control
  - Volume Control
  - Pressure Control

Ventilator modes

- Assist Control - Volume Control
  - RR
  - VT
  - PEEP
  - FiO2

- Assist Control - Pressure Control
  - RR
  - DP*
  - PEEP
  - FiO2
Ventilation and Oxygenation

- RR $\times$ VT = minute ventilation

Inspiratory time and expiratory time

- I:E ratio = how much time spent in inspiration vs expiration

<table>
<thead>
<tr>
<th>↑ I:E</th>
<th>↓ I:E</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑ Oxygenation</td>
<td>↑ Ventilation</td>
</tr>
<tr>
<td>↓ Ventilation</td>
<td>↓ Oxygenation</td>
</tr>
</tbody>
</table>
**Inspiratory time and expiratory time**

- **I:E ratio** = how much time spent in inspiration vs expiration
  - Normal = 1:1.5 or higher

- Ways to control this depending on ventilator and mode
  - **I-time (seconds)**
    - usually 1-1.5 sec
  - **Flow rate (L/min)**
    - usually 60-120 L/min

<table>
<thead>
<tr>
<th>I-time</th>
<th>RR</th>
<th>Inspiration</th>
<th>Expiration</th>
<th>I:E ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 sec</td>
<td>20</td>
<td>30 seconds</td>
<td>30 seconds</td>
<td>1:1</td>
</tr>
<tr>
<td>1 sec</td>
<td>20</td>
<td>20 seconds</td>
<td>40 seconds</td>
<td>1:2</td>
</tr>
</tbody>
</table>

**Picking and changing settings**

1. Match their initial needs
2. Adjust as needs change
3. Avoid iatrogenic damage
Picking and changing settings

1. Match their initial needs
2. Adjust as needs change
3. Avoid iatrogenic damage

Initial settings - hypoxemic respiratory failure with or at risk for ARDS

**Assist Control - Volume Control**

<table>
<thead>
<tr>
<th>RR</th>
<th>VT</th>
<th>PEEP</th>
<th>FiO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-24 bpm</td>
<td>6-8 mL/kg PBW</td>
<td>5-10 cmH₂O</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Assist Control - Pressure Control**

<table>
<thead>
<tr>
<th>RR</th>
<th>DP</th>
<th>PEEP</th>
<th>FiO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-24 bpm</td>
<td>15 cmH₂O</td>
<td>5-10 cmH₂O</td>
<td>100%</td>
</tr>
</tbody>
</table>
**Initial settings - obstructive lung disease (COPD or asthma)**

<table>
<thead>
<tr>
<th></th>
<th>RR</th>
<th>VT</th>
<th>PEEP</th>
<th>FiO2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assist Control - Volume Control</strong></td>
<td>10-14 bpm</td>
<td>8 mL/kg PBW</td>
<td>0-5 cmH₂O</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>RR</th>
<th>DP</th>
<th>PEEP</th>
<th>FiO2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assist Control - Pressure Control</strong></td>
<td>10-14 bpm</td>
<td>15-20 cmH₂O</td>
<td>0-5 cmH₂O</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Initial settings - metabolic acidosis (DKA, AKI, shock, toxins)**

**Pressure Support**

<table>
<thead>
<tr>
<th>RR</th>
<th>PS</th>
<th>PEEP</th>
<th>FiO2</th>
</tr>
</thead>
</table>

Example:

Initial values of pH 7 / PaCO₂ 14 with HCO₃⁻ 5 mmol/L

+ “normal” assist control settings

→ ineffective ventilation and worsening acidosis
Initial settings-
metabolic acidosis
(DKA, AKI, shock, toxins)

<table>
<thead>
<tr>
<th>RR</th>
<th>PS</th>
<th>PEEP</th>
<th>FiO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10-5 cmH(_2)O</td>
<td>5-10 cmH(_2)O</td>
<td>100%</td>
</tr>
</tbody>
</table>

Example: Initial values of pH 7 / PaCO\(_2\) 14 with HCO\(_3\) 5 mmol/L + “normal” assist control settings
→ ineffective ventilation and worsening acidosis

Picking and changing settings

1. Match their initial needs
2. Adjust as needs change
3. Avoid iatrogenic damage
Monitors & Goals

- Blood gas
  - pH
  - PaCO₂
  - PaO₂
- Pulse oximetry
  - SpO₂

- Oxygenation
  - PaO₂ ~60 mmHg
  - SpO₂ ~90%

- Ventilation
  - pH 7.2-7.45
  - PaCO₂
    - permissive hypercapnia except with increased intracranial pressure

Adjusting for oxygenation or ventilation

<table>
<thead>
<tr>
<th></th>
<th>RR</th>
<th>Vₜ</th>
<th>PEEP</th>
<th>FiO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>PaO₂ too low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PaO₂ too high</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH too low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH 7.1 / PaCO₂ 70</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*hypoventilating so</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>increase minute ventilation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH too high</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH 7.5 / PaCO₂ 30</td>
<td>↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*hyperventilating so</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>decrease minute ventilation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Picking and changing settings

1. Match their initial needs
2. Adjust as needs change
3. Avoid iatrogenic damage

Issues to avoid with mechanical ventilation

- Volutrauma
- Auto peeping
Volutrauma

• Also known as overdistention of alveoli

• More important contributor to ventilator induced lung injury than barotrauma
  • Recommend conservative tidal volumes
  • Specifically low tidal volume ventilation with ARDS

Auto peeping

• Also known as “dynamic hyperinflation” or “breath stacking”

• What it is:
  • When not enough time to exhale before a new breath is delivered

• Why it is bad:
  • Not appropriately ventilating
  • Thoracic over-inflation can lead to cardiovascular compromise
## Auto peeping

- **How to tell:**
  - Ventilator flow waveform
  - Expiratory hold maneuver
- **What to do:**
  - Decrease respiratory rate
  - Lower I:E ratio
    - Shorter inspiration time and longer expiration time

## Mechanical ventilation topics

1. **Ventilators**
   - a) Modes
   - b) Oxygenation and ventilation
   - c) Settings
2. **ARDS**
   - a) Low tidal volume ventilation
   - b) Prone positioning
3. **Refractory hypoxemia**
4. **Liberation from the vent**
ARDS definition

<table>
<thead>
<tr>
<th>Imaging</th>
<th>Bilateral opacities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Etiology</td>
<td>Not fully explained by heart failure or volume overload</td>
</tr>
<tr>
<td>Timing</td>
<td>≤ 1 week since onset or insult</td>
</tr>
<tr>
<td>Severity: (with PEEP ≥ 5)</td>
<td>Mild ARDS</td>
</tr>
<tr>
<td>PaO₂/FiO₂ ratio</td>
<td>200-300 mmHg</td>
</tr>
<tr>
<td>PaO₂</td>
<td>150</td>
</tr>
<tr>
<td>FiO₂</td>
<td>0.5</td>
</tr>
<tr>
<td>PaO₂</td>
<td>50</td>
</tr>
<tr>
<td>FiO₂</td>
<td>1.0</td>
</tr>
</tbody>
</table>

1. Diagnose ARDS
2. Set up ventilator with low tidal volume ventilation
   • 6 mL/kg PBW, as based on sex and height
3. Adjust Vₜ and RR to reach pH and plateau pressure goals
4. Adjust PEEP and FiO₂ to reach oxygenation goal
Plateau pressure

- Plateau pressure goal ≤ 30 mmHg
- Measure Pplat every 4 hours and with changes in PEEP or VT
Plateau pressure

• If Pplat > 30:
  • decrease V_T by 1 mL/kg incrementally (minimum = 4 mL/kg)

• If Pplat < 25 and V_T < 6 mL/kg:
  • increase V_T by 1 mL/kg until Pplat > 25 or V_T 6 mL/kg

• If Pplat < 30 and breath stacking or dyssynchrony:
  • increase V_T by 1 mL/kg incrementally to 7-8 mL/kg if Pplat remains ≤ 30

---

INCLUSION CRITERIA: Acute onset of
1. PaO2/FiO2 ≤ 300 (corrected for altitude)
2. Bilateral (patchy, diffuse, or homogeneous) infiltrates consistent with
   pulmonary edema
3. No clinical evidence of left atrial hypertension

PART I: VENTILATOR SETUP AND ADJUSTMENT
1. Calculate predicted body weight (PBW)
   Males = 50 + 2.3 (height [inches] - 60)
   Females = 48.5 + 2.3 (height [inches] - 60)
2. Select any ventilator mode
3. Set ventilator settings to achieve initial V_T = 8 mL/kg PBW
4. Reduce V_T by 1 mL/kg at intervals ≤ 2 hours until V_T = 6 mL/kg PBW
5. Set initial rate to approximate baseline minute ventilation (not > 35
   breaths/min)
6. Adjust V_T and RR to achieve pH and plateau pressure goals below.

---

OXYGENATION GOAL: PaO2 55-80 mmHg or SpO2 88-95%
Use a minimum PEEP of 5 cm H2O. Consider use of Incremental FiO2/PEEP
combinations as shown below (not required) to achieve goal.

Lower PEEP/Highest FiO2
| FiO2 | 0.3 | 0.4 | 0.4 | 0.5 | 0.5 | 0.6 | 0.7 | 0.7 |
| PEEP | 5   | 5   | 8   | 8   | 10  | 10  | 10  | 12  |

| FiO2 | 0.7 | 0.8 | 0.9 | 0.9 | 1.0 |
| PEEP | 14  | 14  | 14  | 16  | 18  |

Higher PEEP/lowest FiO2
| FiO2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 |
| PEEP | 5   | 8   | 10  | 12  | 14  | 14  | 16  | 16  |

| FiO2 | 0.5 | 0.5 | 0.8 | 0.8 | 0.9 | 1.0 |
| PEEP | 18  | 20  | 22  | 22  | 22  | 24  |

PLATEAU PRESSURE GOAL: ≤ 30 cm H2O
Check Pplat (0.5 second inspiratory pause), at least q 4h and after each
change in PEEP or V_T
If Pplat > 30 cm H2O: decrease V_T by 1 mL/kg steps (minimum = 4
mL/kg).
If Pplat > 25 cm H2O and V_T < 6 mL/kg, increase V_T by 1 mL/kg until
Pplat > 25 cm H2O or V_T = 6 mL/kg
If Pplat < 25 and breath stacking or dys-synchrony occurs: may
increase V_T in 1mL/kg increments to 7 or 8 mL/kg if Pplat remains ≤ 30 cm H2O.
Other therapies for ARDS

- Prone positioning
- ECMO

Prone positioning

- Early prone positioning in severe ARDS has mortality benefit
  - Consider early on in patient’s course if P:F < 150
- How it works:
  - ↓ compression of left lung by the heart
  - ↓ dependent atelectasis from interstitial edema
  - Allows more lung regions to be functional
  - Improves V/Q mismatch
**Prone positioning - contraindications**

- **Absolute contraindication:**
  - Open wound of neck, chest, or abdomen

- **Relative contraindications:**
  - Hemodynamic instability
  - Elevated intracranial pressure
  - Recent trauma or surgery
    - Unstable fractures
    - Face/neck 15 days
    - Sternotomy 30 days
  - Pregnancy
  - >20% BSA burns
  - Requiring impending surgery/procedure

---

**Prone positioning – logistics**

- **P:F < 150**
  - Manually prone patient x 16+ hours
  - FiO₂ < 100%
  - AND SpO₂ > 92% or PaCO₂ > 70%
  - Supine for up to 6 hours for care

- Prone trial failed if hemodynamic or respiratory instability

- Return to supine
Prone positioning – logistics

- P:F < 150
  - Manually prone patient x 16+ hours
  - PEEP ≤ 10
    - FiO2 ≤ 60%
    - Prone trial failed if hemodynamic or respiratory instability
    - Return to supine
  - FiO2 < 100%
    - AND SpO2 > 92% or PaO2 > 70%
    - Supine for up to 6 hours for care

Mechanical ventilation topics

1. Ventilators
   a) Modes
   b) Oxygenation and ventilation
   c) Settings
2. ARDS
   a) Low tidal volume ventilation
   b) Prone positioning
3. Refractory hypoxemia
4. Liberation from the vent
## Refractory hypoxemia

- Prone positioning
- ECMO
- Inhaled epoprostenol or nitric oxide
- Neuromuscular blockade

Caution against nebulized medications with confirmed COVID-19 or PUI

## Neuromuscular blockade

- 2010 ACURASYS trial → mortality benefit
- 2019 ROSE trial → no mortality benefit compared to lighter sedation

- Bottom line:
  - Not needed for all ARDS patients
  - Still useful for significant vent dyssynchrony OR refractory hypoxemia

- If used:
  - Ensure adequate continuous sedation and analgesia
  - Ensure DVT prophylaxis
Mechanical ventilation topics

1. Ventilators
   a) Modes
   b) Oxygenation and ventilation
   c) Settings
2. ARDS
   a) Low tidal volume ventilation
   b) Prone positioning
3. Refractory hypoxemia
4. Liberation from the vent

The ICU Liberation Bundle = ABCDEF bundle

- A = assess, prevent, manage pain
- B = both SAT + SBT
- C = choice of analgesia and sedation
- D = delirium: assess, prevent, and manage
- E = early mobility and exercise
- F = family engagement and empowerment
SAT + SBT

**SAT**

<table>
<thead>
<tr>
<th>Criteria:</th>
<th>Performance:</th>
<th>Failure:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• No active seizures, withdrawal, myocardial ischemia, elevated ICP</td>
<td>• Hold all continuous sedation</td>
<td>• Anxiety, agitation, pain, RR &gt; 35, SpO₂ &lt; 88%, Acute arrhythmia</td>
</tr>
</tbody>
</table>

**SBT**

<table>
<thead>
<tr>
<th>Criteria:</th>
<th>Performance:</th>
<th>Failure:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• SpO₂ ≥ 88% • PEEP ≤ 8 • FiO₂ ≤ 50% • Hemodynamically stable</td>
<td>• 30-60 minutes of minimal vent support</td>
<td>• RR &gt; 35 or &lt; 8, SpO₂ &lt; 88%, Respiratory distress, Mental status change, Acute arrhythmia</td>
</tr>
</tbody>
</table>

- **Resume sedation at ½ dose**
- **Resume prior vent settings**

**Daily to determine if eligible for extubation**